

Quantitative Measurement and Spatial Characteristics of the Green Innovation Effect of High-Tech Industrial Agglomeration in Fujian Province China

Chenxuan Wang^{1,*}, Wanping Huan¹, Li Chen², Can Tu²

¹Xiamen University of Technology, Xiamen, Fujian, China

²Anhui Jianzhu University, Hefei, Anhui, China

**Corresponding Author*

Abstract: Based on the panel data of Fujian Province from 2010 to 2023, this study uses the spatial specialization measure to calculate the massment degree of advanced-edge sectors and the Super-SBM formulation to compute the ecological advancement effectiveness, aiming to explore the effect and spatial dynamic characteristics of advanced-edge sectors massment on Ecological Advancement in Fujian (FJ) Area. The results show that from 2010 to 2023, the congregation of high-tech sectors in FJ Area showed a steady upward trend as a whole, but there were significant differences in agglomeration levels among regions with different evolutionary characteristics. The average value of Ecological Advancement proficiency of advanced-edge sectors in Fujian Province from 2010 to 2023 was about 0.48, which was the lowest in 2010 (only 0.324) and the highest in 2016 (That is 0.652). The median Ecological Advancement proficiency in southern Fujian and eastern Fujian ranked the top two, which were higher than the provincial average, while the average green innovation efficiency in western FJ, northern FJ and central FJ were all lower than the provincial average. The overall fluctuation range of Fujian Province was small, but the fluctuation range of northern Fujian was relatively large. In addition, the congregation intensity extent of advanced-edge sectors in FJ Area and the Ecological Advancement proficiency showed a synchronous upward direction, and there existed a pronounced beneficial correlation between them.

Keywords: Congregation of Cutting-Edge Sectors; Ecological Advancement Proficiency; Super-SBM; Fujian; Quantitative Measurement

1. Introduction

High-quality development constitutes the primary task in advancing Chinese-style modernization, and advancing low-carbon metamorphosis of socioeconomic development serves as a core link in realizing such advancement. Capital, technology, talent—these factors of production—conglomerate within a defined geographical ambit, thereby engendering economies of scale that precipitate a synergistic outcome wherein the aggregate exceeds the sum of its parts. This phenomenon constitutes industrial agglomeration. Enterprises nestled within such agglomerated precincts partake in the communal utilization of human capital, technological wherewithal, and infrastructural amenities, thereby abating R&D expenditures, while concurrently amplifying the spillover effect of knowledge—a dynamic markedly antithetical to conventional paradigms. Green innovation, anchorage in the precept of sustainable development, effectuates a felicitous symbiosis between economic profitability and ecological integrity, attaining a duple win that subserves both prosperity and environmental preservice. It curbs environmental pollution and resource consumption, facilitating the harmonized advancement of socioeconomic progress and the symbiotic environment. Against this backdrop, quantitatively measuring the Ecological Advancement contribution of frontier technological productive congregation in Fujian Province and exploring its spatial characteristics is of great significance.

2. Literature Review

From the perspective of existing academic research results, the academic circle has generally confirmed that frontier technological productive congregation has a pronounced enabling influence on territorial Ecological Advancement. Yang et al. (2020) pointed out

that it significantly promotes green technological innovation performance [1]. He et al. (2022) argued it not only improves green innovation efficiency but also alleviates the suppressive influence of production factor distortion on it [2]. In addition, Liu et al. (2024) found industrial symbiotic agglomeration promotes green technological innovation [3]. Chang et al. (2023) showed sectoral synergy congregation improves local Ecological Advancement proficiency and produces positive geographic spillovers on surrounding regions[4].JIN et al. (2024) found the data-driven economy has a pronounced beneficial influence on Ecological Advancement proficiency[5].Wang and Zhang (2023) [6] adopted the SBM-DEA model to investigate the regional differentiation and geographical clustering of China's Ecological Advancement proficiency (2007–2019), concluding that unbalanced development is prominent in eastern China. Liu and Li (2023) [7] employed the Super-SBM formulation to compute provincial Ecological Advancement proficiency, showing steady growth in high-tech agglomeration but low overall green innovation efficiency. Wang et al. (2025) [8] empirically explored the vehicle of frontier technological productive congregation, finding it significantly improves local green technological innovation efficiency but inhibits neighboring provinces. Tian and Zhang (2023) empirically concluded the overall level of virtual agglomeration across Chinese provinces, noting most provinces belong to two high-high spatial clustering types[9].

To sum up, existing research has achieved fruitful outcomes regarding the influence of frontier technological productive congregation on Ecological Advancement. This investigation focuses on frontier technological productive congregation, green innovation in FJ Area, and their spatial characteristics.

3. Methodology

3.1 Model Construction

Traditional DEA models fail to account for the excesses and shortfalls of inputs and outputs, and cannot effectively calculate efficiency values involving undesirable outputs. The SBM model proposed by Tone introduces slack variables, which effectively overcomes the limitations of conventional DEA models. On this basis, the super-proficiency SBM formulation is further developed to distinguish productive

decision-making items more precisely. To acquire more precise proficiency measurement outcomes, this research adopts the Super-SBM model to calculate Ecological Advancement proficiency. The mathematical mathematical formulation of the Super-SBM approach is specified as set forth below:

$$\rho = \min \frac{\frac{1}{m} \sum_{i=1}^m \bar{x}_i}{\frac{1}{S_1 + S_2} \left(\sum_{r=1}^{s_1} \frac{\bar{y}_r^g}{y_{r0}^g} + \sum_{r=1}^{s_2} \frac{\bar{y}_r^b}{y_{r0}^b} \right)} \quad (1)$$

$$\text{s.t.} \begin{cases} \bar{x} \geq \sum_{j=1, \neq 0}^n \lambda_j x_j \\ \bar{y}_g \leq \sum_{j=1, \neq 0}^n \lambda_j y_j^g \\ \bar{y}_b \geq \sum_{j=1, \neq 0}^n \lambda_j y_j^b \\ \bar{x} \geq x_0, \bar{y}_g \leq y_0^g, \bar{y}_b \geq y_0^b, \lambda \geq 0 \end{cases}$$

Among them, ρ denotes the efficiency value, n represents the number of decision entities. Each decision entities comprises m resource endowments, S_1 expected yields and S_2 undesirable outputs. x refers to the element in the resource endowments matrix, y^g corresponds to the element in the desirable output matrix, y^b denotes the data in the undesirable yieldsmatrix, and λ stands for the weight vector [10].

3.2 Measurement Method of High-Tech Industrial Agglomeration

Considering the critical role of R&D human capital in the frontier technological productive, this paper adopts the location entropy method and takes the equivalent full-time labor input of R&D human capital in the frontier technological productive to measure the agglomeration degree (AGG) of high-tech industry in prefecture-level cities of Fujian Province. The specific calculation formula is as follows:

$$AGG_{it} = \frac{H_{it}/H_t}{Q_{it}/Q_t} \quad (2)$$

In the formula: H_{it} represents the equivalent full-time labor input of R&D human capital in advanced-edge sectors of locality i during the t -th year; H_t denotes the total equivalent full-time labor input of R&D human capital in advanced-edge sectors of FJ Province in year t ; Q_{it} is the overall equivalent full-time labor input of R&D personnel in locality i during the t -th year, Q_t refers to the overall equivalent full-time labor input of R&D human capital in Fujian Province in year t . A larger value of AGG_{it} indicates a higher agglomeration level of advanced-edge sectors in the corresponding

region.

3.3 Measurement Approach of Green Advancement Proficiency for Frontier Technological Productive

When quantifying the Ecological Advancement proficiency of the frontier technological productive, economic, environmental and innovative factors should be taken into account. Therefore, this paper constructs a resource endowments-yields measurement framework for ecological advancement proficiency assessment grounded in prior research of Liu Jie, Wang Jinhe and Wang Di. The specific indicators are presented in Table 1.

Table 1. Resource Endowments -Yields Measurement Framework of Ecological Advancement proficiency

Indicators	Variable Name	Specific Indicators
Input Indicators	Labor Input	equivalent full-time labor input; R&D personnel
	Capital Input	Internal expenditure on R&D funds
	Energy Input	Total social electricity consumption
Non-input Indicators	Desirable Output	Number of granted patents
		Sales revenue of new products
	Undesirable Output	Sulfur dioxide emissions Total wastewater discharge

3.4 Data Sources

This paper selects the panel data of prefecture FJ's prefectural cities during 2010–2023 as the research sample. Meanwhile, Fujian Province is divided into five major regions, namely Eastern Fujian, Southern Fujian, Western Fujian, Northern Fujian and Central Fujian, based on geographical characteristics and cultural traditions. Eastern Fujian includes Fuzhou and Ningde; Southern Fujian covers Xiamen, Zhangzhou and Quanzhou; Western Fujian consists of Longyan; Northern Fujian refers to Nanping; and Central Fujian comprises Putian and Sanming. The original data of each indicator are derived from the FJ S&T Yearbook, Fujian Social and Scientific Statistical Data, Fujian Statistical Yearbook over the years, in conjunction with the official the NBS web portal and statistical yearbooks of each prefecture-level city. For missing data in individual years, interpolation method is adopted to supplement the missing values by using STATA software.

4. Results of Green Innovation Effect of High-Tech Industrial Agglomeration

The measurement results and analysis of the ecological advancement influence of frontier technological productive agglomeration are presented as follows.

4.1 Measurement of Agglomeration Level of High-Tech Industry

Specialization index is adopted to estimate the agglomeration extent of high-tech prefectural-level industry of FJ Area. The average values during 2010–2023 are shown in Table 2.

Table 2. Agglomeration Degree and Ranking of High-Tech Industry in Cities of Fujian Province (2010–2023)

Region	Mean of AGG	Ranking
Fuzhou City	1.30698	3
Ningde City	2.01067	1
Xiamen City	1.31707	2
Zhangzhou City	0.76002	4
Quanzhou City	0.29337	8
Longyan City	0.37429	6
Nanping City	0.35632	7
Sanming City	0.22265	9
Putian City	0.49295	5

As shown in Table 2, the average congregation level of advanced technology industry in Fujian Area is approximately 0.71. Eastern Fujian presents the highest industrial agglomeration level, which can be attributed to the leading role of flagship enterprises and prominent industrial cluster advantages in this region. The congregation standard of Southern Fujian is somewhat superior than the provincial average. By contrast, Western Fujian, Northern Fujian and Central Fujian exhibit relatively low agglomeration levels, all below the provincial average. This is mainly restricted by geographical conditions, which hinder the formation of large-scale industrial chains, accompanied by shortages of innovation resources and professional talents.

As illustrated in Table 3, the general concentration degree of advanced technology sector in Fujian Province shows an upward trend from 2010 to 2023. Eastern Fujian maintains the highest concentration degree above the provincial average line with drastic fluctuating growth. Southern Fujian experiences an obvious fluctuating pattern of decline followed by rise during 2011–2017. The cutting-edge technological industry concentration degrees in

Fujian Province were 0.436, 1.054, and 0.901 in 2010, 2022, and 2024, individually. In eastern Fujian, the cutting-edge technological industry concentration degrees were 0.884, 1.406, 1.518, 1.430, 2.459, and 2.271 in 2010, 2013, 2015, 2016, 2022, and 2023, individually. In southern Fujian, the degrees were 0.646, 0.604, 0.761, 0.926, 0.988, and 0.847 in 2010, 2013, 2016, 2017, 2019, and 2021, separately. In western Fujian, the degrees were 0.165, 0.208, 0.163, 0.117, 0.348, 0.466, 0.541, and 0.664 in 2010, 2012, 2013, 2014, 2017, 2018, 2019, and 2022,

separately. In northern Fujian, the cutting-edge technological industry concentration levels were 0.1726, 0.470, and 0.509 in 2021, 2022, and 2023, separately. The region subsequently recedes to 0.447 in 2023. Central FJ commences at 0.313 in 2010, experiences a short-lived decline to 0.248 in 2011, then demonstrates a relatively stable trajectory with values ranging between 0.294 and 0.448 over the remaining period—the coefficient of variation for Central FJ is a mere 0.16.

Table 3. Trend of Average Agglomeration Level of High-Tech Industry in Various Regions of Fujian Province

year	Industrial Agglomeration Mean				
	Eastern Fujian	Southern Fujian	Western Fujian	Northern Fujian	Central Fujian
2010	0.8840	0.6455	0.1655	0.1726	0.3125
2011	0.9595	0.7212	0.1845	0.2769	0.2480
2012	0.7860	0.7836	0.2084	0.2931	0.3474
2013	1.4063	0.6035	0.1631	0.2995	0.3267
2014	1.4929	0.6049	0.1170	0.3713	0.2941
2015	1.5180	0.6433	0.2253	0.3634	0.3424
2016	1.4303	0.7607	0.2570	0.2561	0.3710
2017	1.5103	0.9256	0.3481	0.3979	0.3644
2018	1.8134	0.9058	0.4658	0.3802	0.4471
2019	1.9709	0.9885	0.5408	0.3629	0.4476
2020	2.3292	0.9058	0.6527	0.3892	0.4114
2021	2.3933	0.8467	0.6476	0.4702	0.3730
2022	2.4589	0.8571	0.6637	0.5086	0.3922
2023	2.2705	0.8700	0.6005	0.4466	0.3313

4.2 Measurement Results of Green Innovation Efficiency

This research adopts the Super-SBM approach and selects the Resource endowments -Yields factors of ecological advancement efficiency in Table 1 to measure the green innovation efficiency of high-tech industry in prefecture-level cities of Fujian Province during 2010–2023. The measurement results are presented, and the corresponding changing trends are shown in Table 4.

As can be seen from Table 4, the top three prefecture-level urban areas with respect to the

average ecological advancement proficiency of the cutting-edge industry in Fujian Province are Xiamen, Quanzhou and Ningde. There are obvious disparities among cities. Xiamen records the highest average green innovation efficiency, while Putian has the lowest, with a gap of approximately 0.63. The average values of Fuzhou and Longyan are relatively close to each other.

In the initial year of 2010, the proficiency values cluster within a relatively narrow bandwidth, ranging from Nanping's 0.230 to Fuzhou's 0.494, with Xiamen registering 0.406 and Ningde at 0.341

Table 4. Green Innovation Efficiency of High-Tech Industry in Various Regions of Fujian Province (2010–2023)

year	Fuzhou	Xiamen	Putian	Sanming	Qanzhou	Zhangzhou	Nanping	Longyan	Ningde
2010	0.494	0.406	0.109	0.372	0.221	0.397	0.230	0.344	0.341
2011	0.420	0.605	0.174	0.451	0.502	0.446	1.007	0.377	0.267
2012	0.378	1.047	0.226	0.396	0.415	0.305	0.437	0.215	0.419
2013	0.340	0.813	0.207	0.414	1.064	0.370	0.178	0.364	0.431
2014	0.313	0.587	0.176	0.356	0.634	0.338	0.192	0.396	0.315
2015	0.359	0.614	0.195	0.573	1.038	0.383	0.355	0.340	0.336
2016	0.459	0.654	0.178	1.025	1.026	0.425	0.361	0.594	1.138

2017	0.313	0.619	0.161	0.441	0.760	0.254	0.133	0.392	0.455
2018	0.429	0.885	0.157	0.281	1.073	0.352	0.173	0.531	0.513
2019	0.373	1.015	0.195	0.270	0.477	0.262	0.185	0.540	1.059
2020	0.637	1.080	0.216	0.395	1.088	0.372	0.238	0.780	1.010
2021	0.637	1.029	0.212	0.383	0.416	0.430	0.347	0.495	1.101
2022	0.669	1.039	0.221	0.463	0.328	0.344	0.344	0.450	0.733
2023	0.426	1.0301	0.1562	1.0035	0.265	0.268	0.213	0.344	0.464

In 2010, the green creativity indices of Putian, Nanping, Quanzhou, and Xiamen were 0.109, 1.007, 0.502, and 0.605, separately. In 2012, the green originality indices of Xiamen, Putian, Sanming, and Longyan were 1.047, 0.226, 0.396, and 0.215, individually. In 2016, the green originality indices of Sanming, Ningde, and Quanzhou were 1.025, 1.138, and 1.026, individually. In 2017, the green originality indices of Nanping, Zhangzhou, Putian, Xiamen, Quanzhou, and Ningde were 0.133, 0.254, 0.161, 0.619, 0.760, and 0.455, individually. In 2018,

2019, and 2020, the green originality indices of Xiamen were 0.885, 1.015, and 1.080; those of Quanzhou were 1.073, 0.477, and 1.088; and those of Ningde in 2019 and 2020 were 1.059 and 1.010, individually. The green originality indices of Longyan in 2018 and 2020 were 0.53 and 0.780, individually. In 2021, 2022, and 2023, the green originality indices of Xiamen were 1.029, 1.039, and 1.030, individually; those of Ningde were 1.101, 0.733, and 0.464, individually. In 2023, the green originality index of Sanming reached 1.004.

Table 5. Trend of Average Green Innovation Efficiency of High-Tech Industry in Various Regions of Fujian Province

year	Eastern Fujian	Southern Fujian	Western Fujian	Northern Fujian	Central Fujian
2010	0.41784	0.34165	0.34490	0.23015	0.24066
2011	0.34381	0.51822	0.37770	1.00774	0.31258
2012	0.39915	0.58955	0.21560	0.43710	0.31131
2013	0.38561	0.74929	0.36467	0.17864	0.31098
2014	0.31438	0.52020	0.39619	0.19294	0.26617
2015	0.34778	0.67872	0.34019	0.35567	0.38458
2016	0.79922	0.70235	0.59482	0.36122	0.60214
2017	0.38428	0.54478	0.39261	0.13385	0.30128
2018	0.47139	0.77057	0.53185	0.17302	0.21993
2019	0.71672	0.58528	0.54073	0.18522	0.23309
2020	0.82418	0.84725	0.78074	0.23839	0.30568
2021	0.86988	0.62549	0.49567	0.34797	0.29773
2022	0.70161	0.57086	0.45066	0.34419	0.34280
2023	0.44527	0.52114	0.34400	0.21396	0.57987
Mean value	0.53008	0.61181	0.44074	0.31429	0.33634

As shown in Table 5, the average green originality efficiency across all regions of Fujian Province from 2010 to 2023 was 0.48. The lowest value occurred in 2010 at 0.324, while the highest was reached in 2016 at 0.652. Moreover, it was found that the green originality efficiency in southern and eastern Fujian exceeded the provincial average, whereas that in western, northern, and central Fujian remained below the provincial average.

From a temporal perspective, the average green advancement efficiency indices for Fujian's regions were 0.315, 0.512, 0.390, 0.398, and 0.338 in 2010, 2011, 2012, 2013, and 2014, individually. In 2015, 2016, and 2017, these indices rose to 0.421, 0.612, and 0.351, individually. From 2018 to 2020, the indices

were 0.433, 0.452, and 0.599, individually. In 2021, 2022, and 2023, the indices were 0.527, 0.482, and 0.421, individually. In eastern Fujian, green advancement efficiency was 0.418 in 2010, 0.314 in 2014, and 0.799 in 2016. In 2021 and 2023, the efficiency levels were 0.870 and 0.445, individually. In southern Fujian, green advancement efficiency was 0.342 in 2010, 0.520 in 2014, and 0.847 in 2020. In 2021, 2022, and 2023, the values were 0.625, 0.571, and 0.521, individually. In western Fujian, green advancement efficiency was 0.345 in 2010, 0.216 in 2012, and 0.595 in 2016. In 2023, the efficiency stood at 0.344. In central Fujian, green advancement efficiency was 0.602 in 2016 and 0.580 in 2023. In northern Fujian, green advancement efficiency was 1.008 in 2011,

0.179 in 2013, 0.356 in 2025, and 0.361 in 2026. In 2017, 2021, and 2022, the efficiency levels were 0.134, 0.348, and 0.344 individually.

4.3 Spatial Convergence Characteristics of Green Innovation Effects of Frontier Technological Productive Congregation.

Based on the levels of frontier manufacturing congregation and green innovation, the prefecture-level cities in Fujian Province are partitioned into four classes: frontier (H-H), superior versus inferior (H-L), bottom-tier and bottom-tier (L-L), and low-ranked versus high-ranked (L-H). Taking high-tech industrial agglomeration degree as the abscissa and ecological advancement proficiency as the y-coordinate, all regions are divided into four quadrants according to their respective mean values: high congregation–upper ecological advancement proficiency (H-H), upper congregation–inferior ecological advancement proficiency (H-L), inferior congregation–inferior ecological advancement proficiency (L-L), and low agglomeration–upper ecological advancement proficiency (L-H). The geographical convergence of ecological advancement proficiency driven by frontier technological productive congregation in Fujian Province is further examined through scatter plots for 2010 and 2023.

As illustrated in Figure 1, the provincial overall level remained in the L-L quadrant in 2023. Nevertheless, Eastern Fujian shifted to the H-L quadrant; Southern Fujian and Central Fujian moved to the L-H quadrant; while Western Fujian and Northern Fujian stayed in their original quadrants.

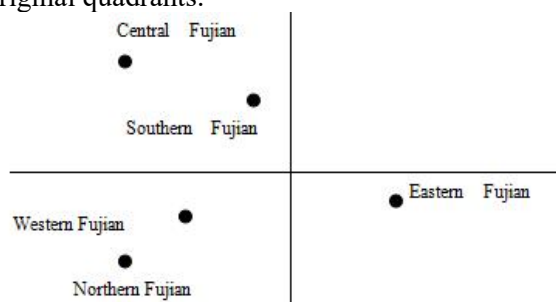


Figure 1. Spatial Characteristics of the Ecological Advancement Influence of Frontier Sectoral Clustering (2023)

Overall, the spatial distribution pattern of frontier industrial congregation and ecological advancement efficiency in FJ Area has evolved from a dominant low concentration–low efficiency pattern toward a coexistence of

inferior congregation–elevated proficiency and high congregation–inferior proficiency. Both industrial congregation degree and ecological advancement proficiency have improved through areas, and frontier technological productive congregation can effectively promote the growth of ecological advancement efficiency.

In addition, the backward advancement risk of Western and Northern Fujian deserves attention. Restricted by terrain conditions, it is difficult for Western and Northern Fujian to form large-scale industrial concentration. Insufficient financial support further limits investment in green technologies, leading to a slow growth in green innovation efficiency. Although Central and Southern Fujian exhibit a slow growth in industrial concentration, they benefit from policy dividends and scientific research advantages, achieving a rapid improvement in green innovation efficiency. However, their industrial layout remains relatively scattered, making it necessary to further strengthen industrial concentration.

In Eastern Fujian, the growth rate of industrial concentration outpaces that of green innovation efficiency. Due to inadequate investment in green technology R&D, leading enterprises within the concentration zone lack sufficient input in energy conservation and emission reduction.

5. Conclusions

This paper employs cross-sectional time-series data of urban areas in FJ Area from 2010 to 2023 as the selected observations to measure the clustering degree of advanced-edge sectors and green innovation efficiency in different regions of Fujian Province and to analyze their spatial characteristics. The Super-SBM formulation is deployed to gauge the ecological advancement proficiency of per area and to analyze the locational attributes of the ecological advancement proficiency of frontier technological productive clustering. The empirical evidence suggests that over 2010–2023, the general clustering extent of advanced-edge sectors in Fujian Province exhibited an upward trend, while significant differences were observed across regions. Although the eastern Fujian area had the highest concentration level, consistently surpassing the overall mean, its scope of fluctuation was the most pronounced. The southern Fujian area was subject to significant fluctuations, first decreasing and then

increasing, between 2011 and 2017. In contrast, the agglomeration levels in northern and central Fujian remained consistently below the overall average, with relatively moderate fluctuations. Meanwhile, although the western Fujian region maintained an upward trend, its agglomeration level had yet to surpass the overall average. Regarding green innovation efficiency, the overall trend in Fujian Province from 2010 to 2023 showed little fluctuation. However, the northern Fujian region exhibited considerable volatility. The average green innovation efficiency in southern and eastern Fujian ranked among the top two in the province, while the average values in western, northern, and central Fujian were all below the provincial average. Observations from scatter plots indicate that the clustering extent of advanced-edge sectors and ecological advancement efficiency in Fujian Province are gradually increasing. A superior level of frontier technological productive congregation aids in the betterment of ecological advancement proficiency; as regional industrial agglomeration increases, green innovation efficiency also improves accordingly.

In view of the previous evidence several recommendations emerge as set forth below. First, governments across different regions of Fujian Province should strengthen policy support to promote technological agglomeration within high-tech industries, guide resource sharing and knowledge dissemination among enterprises, and foster harmonious regional development. At the same time, green technological innovation should be advanced to reduce undesirable outputs and prevent the further widening of regional disparities. Second, industrial technological innovation should be promoted by strengthening the construction of a green innovation system for high-tech industries, establishing green innovation clusters, and building high-tech green industrial parks, thereby achieving the dual goals of high-tech industrial growth and environmental pollution reduction. Third, based on the factor endowments of each area, a factor circulation network and infrastructure connectivity should be established across Fujian Province to maximize the advantages of the "mountain-sea resource" combination, facilitate resource integration, enhance green innovation efficiency, and reduce energy consumption per unit productive output of frontier sectors.

Acknowledgments

Supported by Fujian Social Science Fund Project: Digital Economy-Driven Green Innovation Effects of Fujian High-Tech Agglomeration (FJ2024BF042).

References

- [1] Yang Haochang, Li Lianshui, Zhang Faming(2020).High-tech industrial agglomeration and green technological innovation performance, *Science Research Management*, 41(09): 99-112.
- [2] He Zixin, Hui Ning (2022). Does Factor Market Distortion Inhibit the Improvement of Green Innovation Efficiency? A Research on the Moderating Effect of High-Tech Industrial Agglomeration, *Science & Technology Progress and Policy*, 39(21): 75-84.
- [3] Liu Jun, Qian Yu (2024). A study of the influence of industrial symbiotic agglomeration on green technology innovation, *Science Research Management*, 45(08): 51-61.
- [4] Chang Zhe-ren, Zheng Meng (2023). Impact of Collaborative Industrial Agglomeration on Green Innovation Efficiency from Perspective of Spatial Spillover, *Research on Financial and Economic Issues*, (10):53-67.
- [5] Jin Zining, Song Yangyi (2024).Practical Reflection and Institutional Adjustment on the Application of" Leniency Based on Carbon Sink Subscription" in Environmental Criminal Judicial, *Journal of Nanjing Tech University (Social Science Edition)*,23(01):96-112+114.
- [6] Wang Jinhe, Zhang Lingmei (2023). Regional Differences and Spatial Convergence of Green Innovation Efficiency in China, *Ecological Economy*, 2023, 39(01): 81-86+100.
- [7] Liu Jie, Li Jingshu (2023). Research on the Impact of High-Tech Industrial Agglomeration on Regional Green Innovation Efficiency, *Ecological Economy*, 39(09):68-74+101.
- [8] WangDi, Zhang Zhiyuan, Wang Xiaolong (2025). How can High-tech Industrial Agglomeration Promote Regional Green Technology Innovation? Dual Perspectives of Knowledge Spillovers and Market Competition, *Science & Technology Progress and Policy*, 42 (12):49-58.

- [9] Tian Lin Zhang Shijie (2023). A Study of the Measurement, Spatial Differences and Convergence of Virtual Agglomeration in China, *Journal of Zhejiang University (Humanities and Social Sciences)*, 53(07):75-97.
- [10] Tone K (2002). A slacks-based measure of super-efficiency in data envelopment analysis. *European Journal of Operational Research*, 143: 32-4.